

# Worldwide R&D of Virtual Observatory

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**Abstract.** Virtual Observatory (VO) is a data intensive online astronomical research and education environment, taking advantages of advanced information technologies to achieve seamless and uniform access to astronomical information. The concept of VO was introduced in late of 1990s to meet challenges brought up with data avalanche in astronomy. This paper reviews current status of International Virtual Observatory Alliance, technical highlights from world wide VO projects, and a brief introduction of Chinese Virtual Observatory.

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## 1. Introduction

During the last decade, advances in technologies have been changing the abilities and ambitions of astronomers. New technologies on telescope design and fabrication bring more powerful telescopes than ever to astronomers. Large scale digital sky surveys are prospered with the appearance of CCD mosaic camera. The scale of numerical simulation is also increasing rapidly with the development of hardware and software. As a result of these advances, data avalanche is occurring in Astronomy. Furthermore, driven by multi-waveband sky surveys and observations, new astronomical fields appeared and are becoming more and more popular, for example, multi-waveband research, multi-archive data mining, time domain analysis, precise cosmology, etc (Lawrence (2006)). To meet challenges brought up by the above changes, Virtual Observatory (VO) concept was initiated (Szalay (2001)). Virtual Observatory is a data intensive online astronomical research and education environment, taking advantages of advanced information technologies to achieve seamless and uniform access to astronomical information. The power of the World Wide Web is its transparency. It is as if all the documents in the world are inside your PC. The idea of the VO is to achieve the same transparency for astronomical data and information (Quinn (2004)). VO is a science driven but technic enabled resolution, a cyber-infrastructure for the 21st century astronomy.

## 2. International VO activities

After National Virtual Observatory (US-VO), the first funded VO project, VO projects were initiated in different countries and regions. International Virtual Observatory Alliance (IVOA) was formed in June 2002 with a mission to "facilitate the international coordination and collaboration necessary for the development and deployment of the tools, systems and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating virtual observatory." At present, the IVOA is formed by 16 projects. VO framework includes agreed standards, interoperable data collections, interoperable services and applications. IVOA focuses its work on development of standards. Now, more than 20 specifications have been published by IVOA working groups.

Following the concept of VO and IVOA specifications, a new prosperous era is coming for astronomical softwares and services. New applications, VO-enhanced legacy services are supporting astronomer's research more and more strongly. Core services from US-VO provide functions including data discover, service registry, catalog coverage, object cross match, source extraction and identification. UK VO project, AstroGrid deployed the worlds only unified VO operational service "AstroGrid", which gives astronomers a "one-stop" access to all the worlds astronomy data from its desktop. Many other new applications are release by world-wide VO projects and contributors. For example, VOPlot, VOSpec, VisIVO, SAADA, etc. At the same time, existing applications and systems are upgraded and enhanced to support VO including CDS services (SIMBAD, Vizier, Aladin), NED, SciSoft, IRAF, TOPCAT, Montage, SExtractor, and so on.

### 3. VO in China

Chinese Virtual Observatory (China-VO) is the national VO project in China initiated in 2002 (Cui (2004)). The China-VO aims to provide VO environments for Chinese astronomers. It focuses its research and development on applications and VO science in the following five fields: 1.China-VO Platform, providing VO environments for Chinese astronomical community; 2.Uniform Access to Global Astronomical Resources and Services, importing international resources to Chinese astronomers and sharing Chinese resources to international colleagues; 3.VO-ready Projects and Facilities, collaborating with astronomical projects to prompt they are VO-compliant; 4.VO-based Astronomical Research Activities, guiding and training astronomers to use VO applications and services; 5.VO-based Public Education, developing non-professional services for the public.

During the last several years, several VO applications and services have been initiated and developed by the China-VO. For example, VOFilter, an XML filter for OpenOffice.org Calc to load VOTable files; SkyMouse, a smart interface for astronomical on-line resources and services; FitHAS (FITS Header Archiving System), a toolkit for FITS file providers and data centers; VO-DAS, an OGSA-DAI based service system to provide unified access to astronomy data. Furthermore, the China-VO is tightly collaborating with LAMOST, a Chinese ambitious spectrum sky survey project, to make it is VO-enabled, sharing its archives and software to the VO.

Internet is inter-connected. VO is trying to link on-line resources and services together in a higher level. More and more VO supported resources and services are available. How to do better science using these tools? VO is not a simple thing, but a way of life. Astronomers need learn how to survive in the VO era.

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